

Tomography upgrade Kick off meeting

Detectors, Controls, data format and processing.

Current Status and future direction

Micro Tomography: Detectors, Controls, Data Distribution and Data Analysis. Current Status and Future Direction by Francesco

Tools to Assist with a Multi-Group, Multi-Divisional Project by Claude



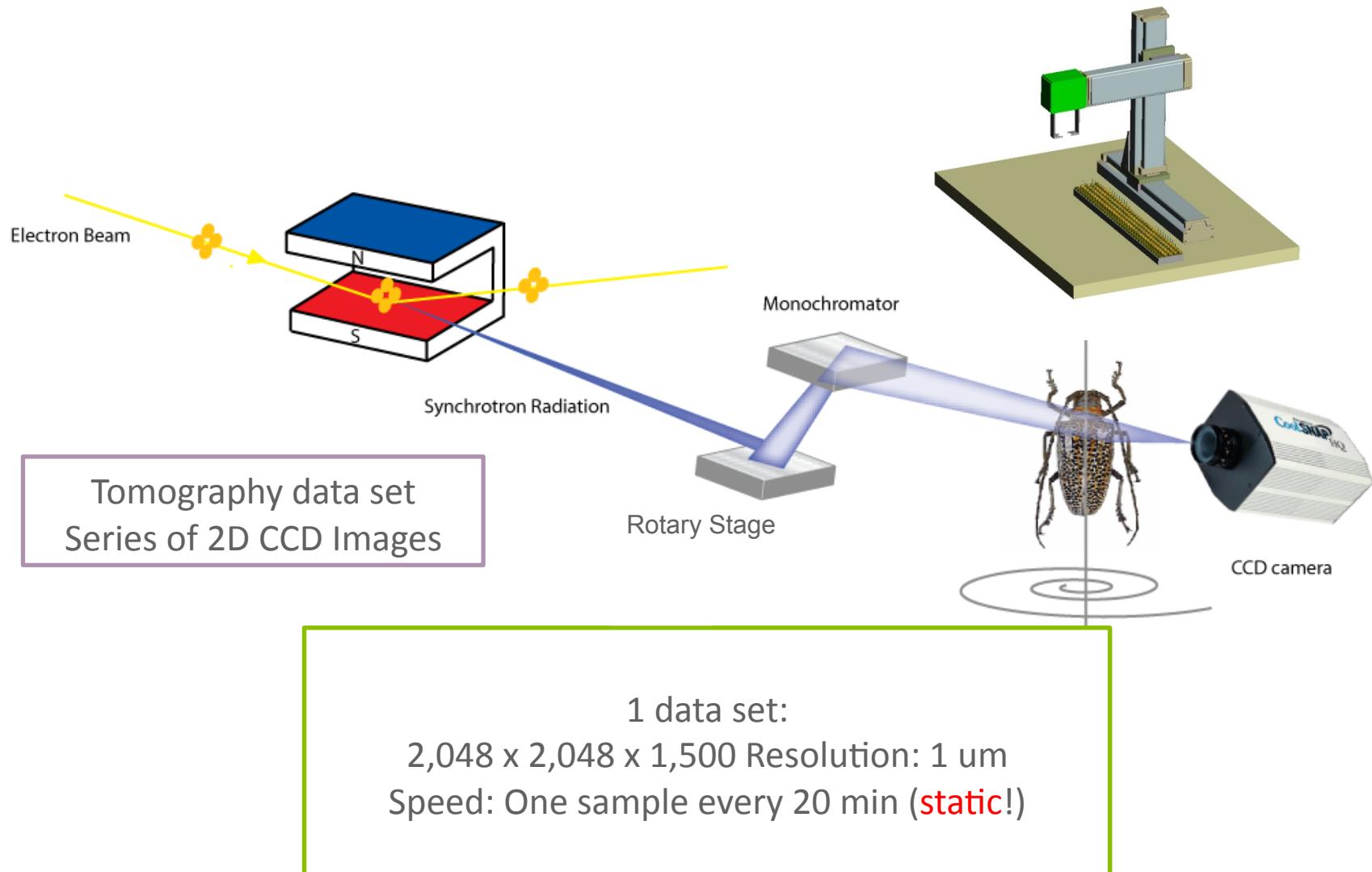
Summary

- Motivation
 - Why we need to change the way we do tomography ?
- Current system
 - Time consuming/routine tasks
 - Control
 - Data handling (format, meta data, transfer, distribution archival)
- Future system
 - Control
 - Data handling



Micro tomography

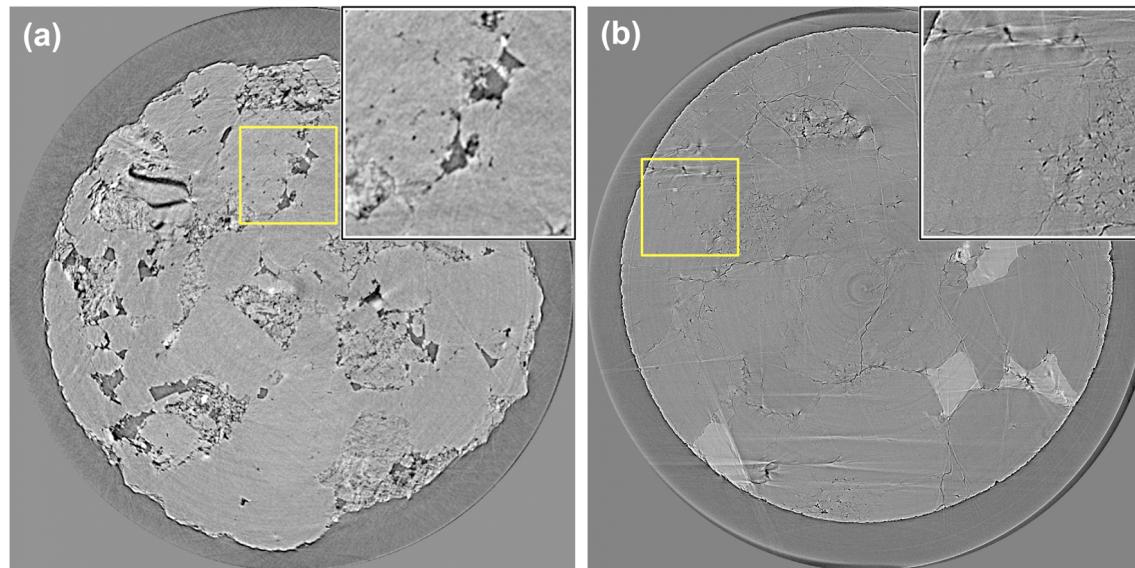
High throughput fully automated 1 μm resolution tomography



Motivations

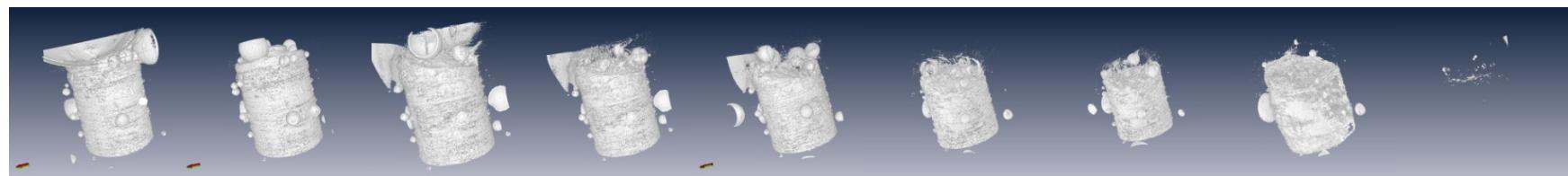
- From static measurements to **in-situ** studies and **3D dynamics**

Thermal expansion cracking in rocks



1 um resolution, sample at 300C with data collected (a) in less than 1 minute. (b) in 25 minute

In situ studies – real time corrosion of Al alloy



High resolution "3D movies" of evolving samples are now within reach

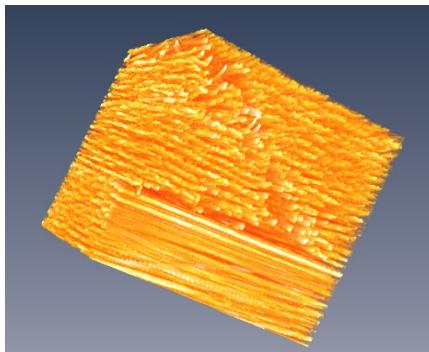


Current Micro tomography: static samples

High throughput fully automated 1 μm resolution tomography



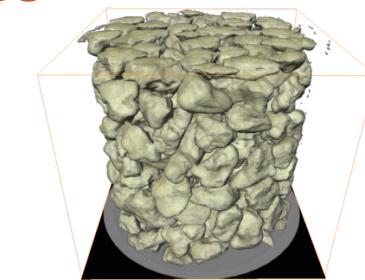
New Reusable Solid Rocket Motors Insulation



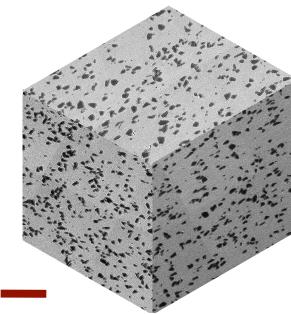
Self healing composite - healing efficiency



Ceramic coating layers

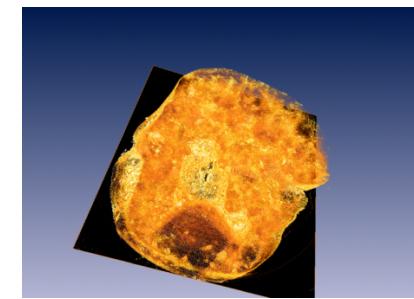


Mechanical behavior of sand under compression



100 μm

Deformation in Particle Reinforced Metal Matrix Composites



Highly Explosive Materials (PBX-9501) Modeling

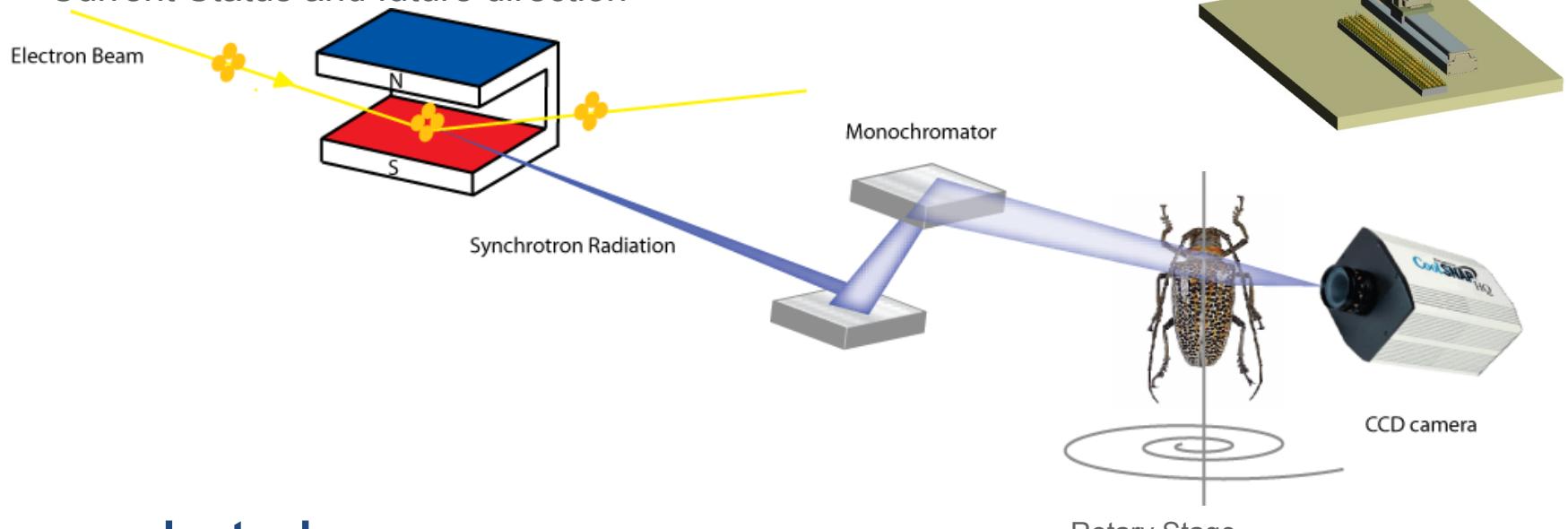
Data handled per sample (every ~ 17 min)

	Pixels	Size
CCD single projection	2,024 x 2,048	8.00 Mbyte
Raw data set	2,024 x 2,048 x 1,440	11.25 Gbyte
Normalized	2,024 x 2,048 x 1,440	22.50 Gbyte
Reconstructed	2,024 x 2,048 x 2,048	32.00 Gbyte
	Total	65.76 Gbyte



Tomography

Detectors, Controls, data format and processing.
Current Status and future direction



Tomography tasks

- Instrument configuration
- Log-book entry
- Collect raw data (stop/go)
- Move raw data
- Analyze data
- Move analyzed data

Detector Integration

- Database Interface: Electronic Log
- Motion control: Fly Scan
- Data Collection: Scan / Environment
- Data Transfer/Distribution: Gridftp
- Data Processing: Cluster Software
- Data File Format: data exchange

DP and BCDA

IS and SSG

BCDA

SSG

IT and MCS

SSG

BCDA



Tomography Experiment Tasks

- Instrument configuration (manual)

- Optimize beamline for a selected energy
- Align tomography system
- Select the correct magnification
- Focus the scintillator screen
- Optimize CCD camera parameters

- Log-book entry (semi-manual)

- User/proposal
- sample name
- instrument status (Energy, Sample/detector distance, scintillator, etc.)

- Collect raw data for a tray of samples (automatic)

- Projection: trigger camera move rotary
- White Field: move sample out, trigger camera
- Dark Field: close shutter, trigger camera

- Move raw data (manual)

- to analysis cluster
- to archive

- Analyze data (semi-automatic)

- log-book entry
- 3D reconstruction
- data reduction

- Move analyzed data (manual)

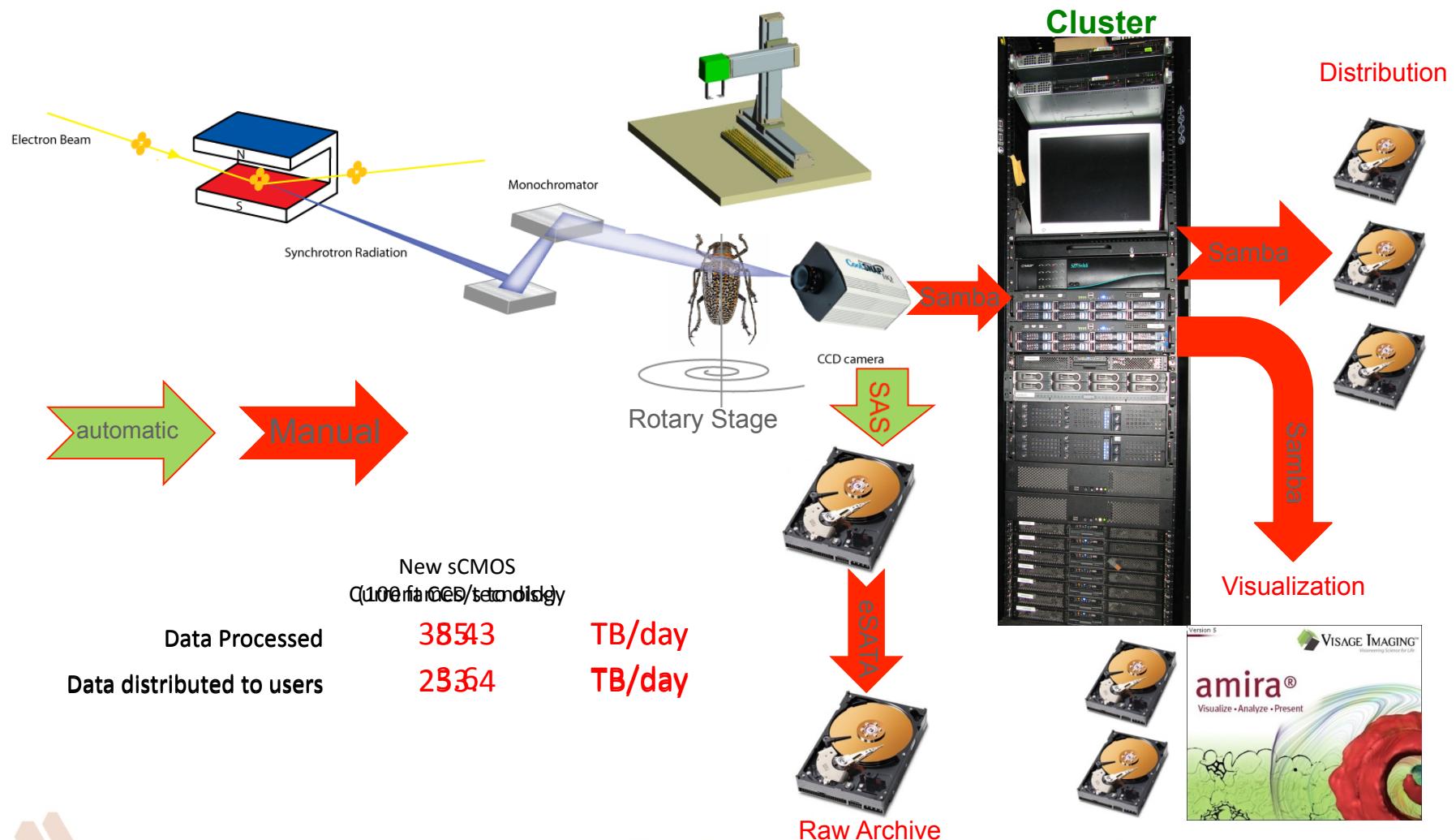
- to user's disks / shipping
- to 3D visualization machine



Tomography of static samples

Current detectors, controls and data flow

Linux
Windows

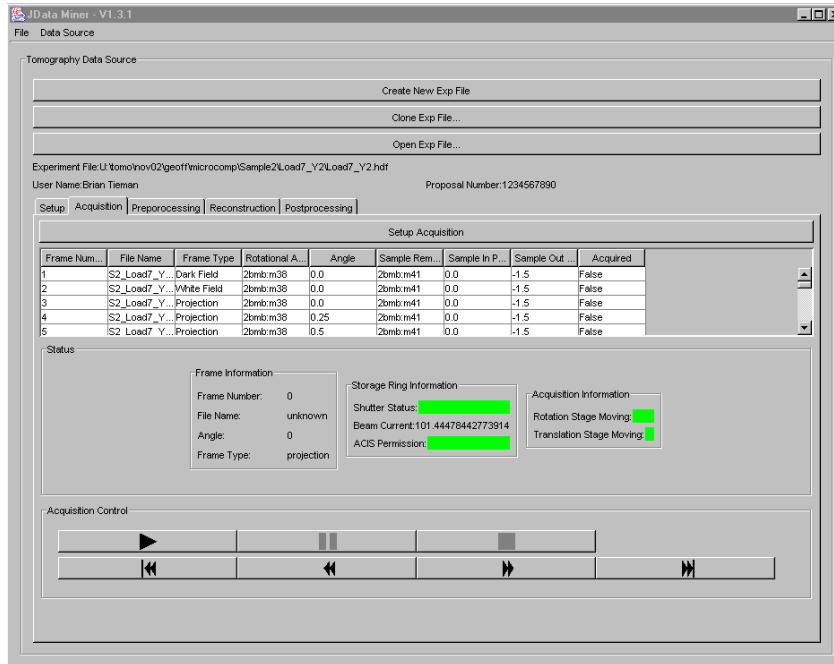


Tomography Experiment Tasks

- Collect raw data for a tray of samples (automatic)

- Projection: trigger camera move rotary
- White Field: move sample out, trigger camera
- Dark Field: close shutter, trigger camera
- unload/load sample

- Repeat



+

- Stable and very reliable
- easy to use
- full integration with beamline, and robot

-

- not flexible
- cannot be controlled by an outer loop
- no scripting



Motivations

From static measurements to **in-situ** studies and **3D dynamics**

How ?

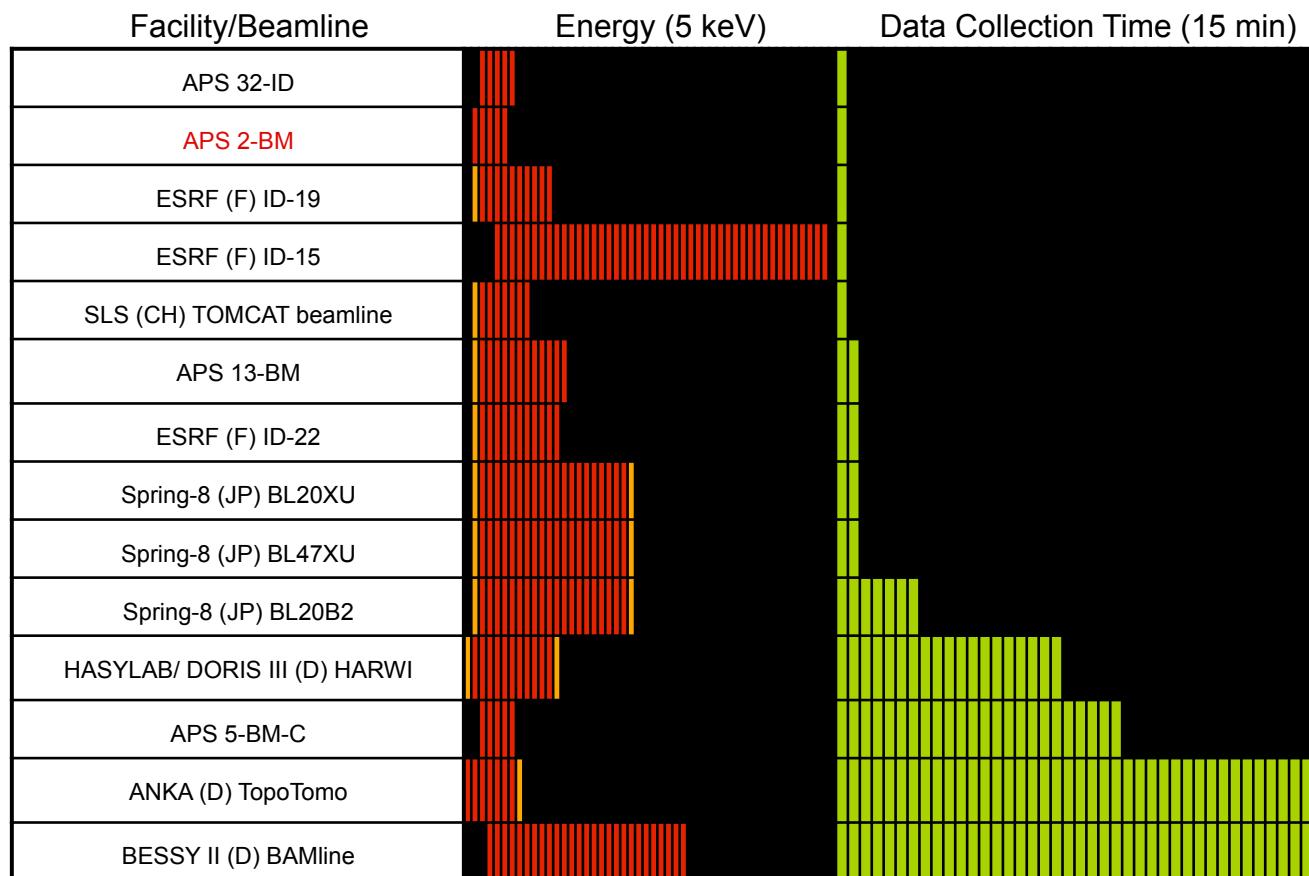
- Reduce data collection overhead
 - on the fly data collection
 - new hardware
 - PCO.dmax memory data collection
 - rotary air bearing
- Control sample environment
 - add flexibility in designing the data collection process
- Faster data analysis
 - new cluster code for CPU and GPU
- Automated data handling
 - raw:
 - Automatic distribution and upload
 - Single file for raw data and meta data
 - Efficient disk I/O, data transfer
 - **Ability to exchange data/users/code among facilities**
 - analyzed:
 - Automatic distribution
 - Flexible format based on user needs
 - Provide plugin for imageJ, Amira, IDL, etc. (avoid data conversion)



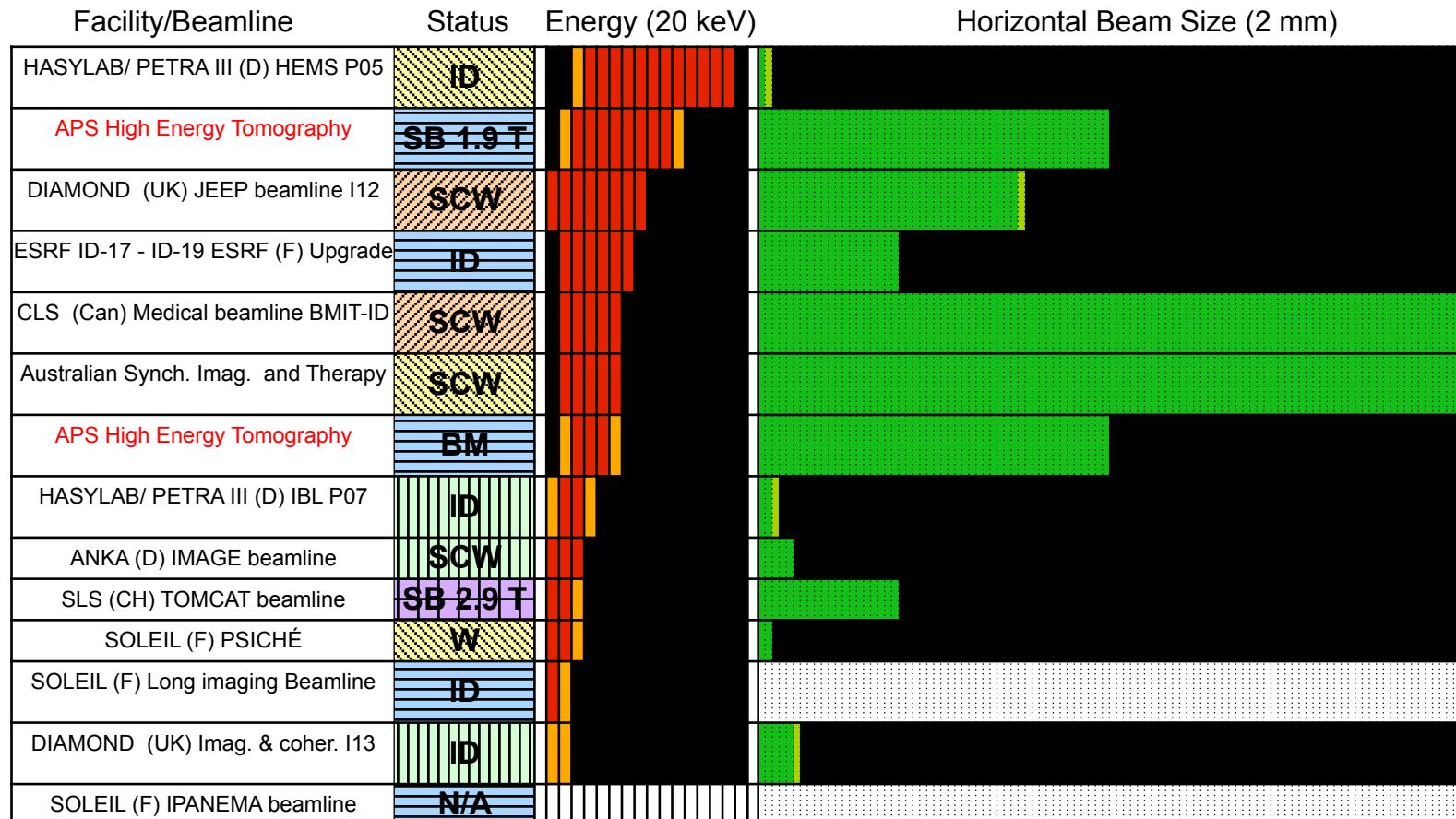
microCT in the US

APS	2-BM 5-33 keV, 25 x 4 mm ² , Dedicated tomography 32-ID 8-35 keV, 2 x 1 mm ² , Dedicated phase-contrast imaging. 13-BM 7-70 keV, 50 x 4 mm ² , Multipurpose for geosciences. (GSECARS). 5-BM 10-42 keV, 30 x 2 mm ² , Multipurpose (materials, polymers). (DND-CAT).
ALS	Beamline 8.3.2. Operational. Superconducting bending magnet source. Energy up to 40 keV. Beamline length 20 m. Maximum beam size 40 x 4.5 mm ² .

and around the world



Future micro-CT facilities



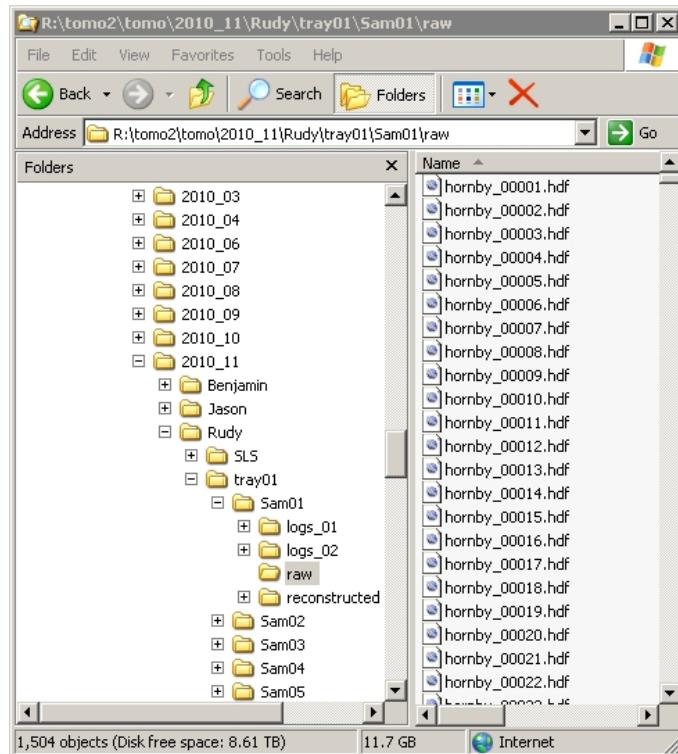
Under consideration	
In the design phase	
Under construction	
Under commissioning	
Operational	



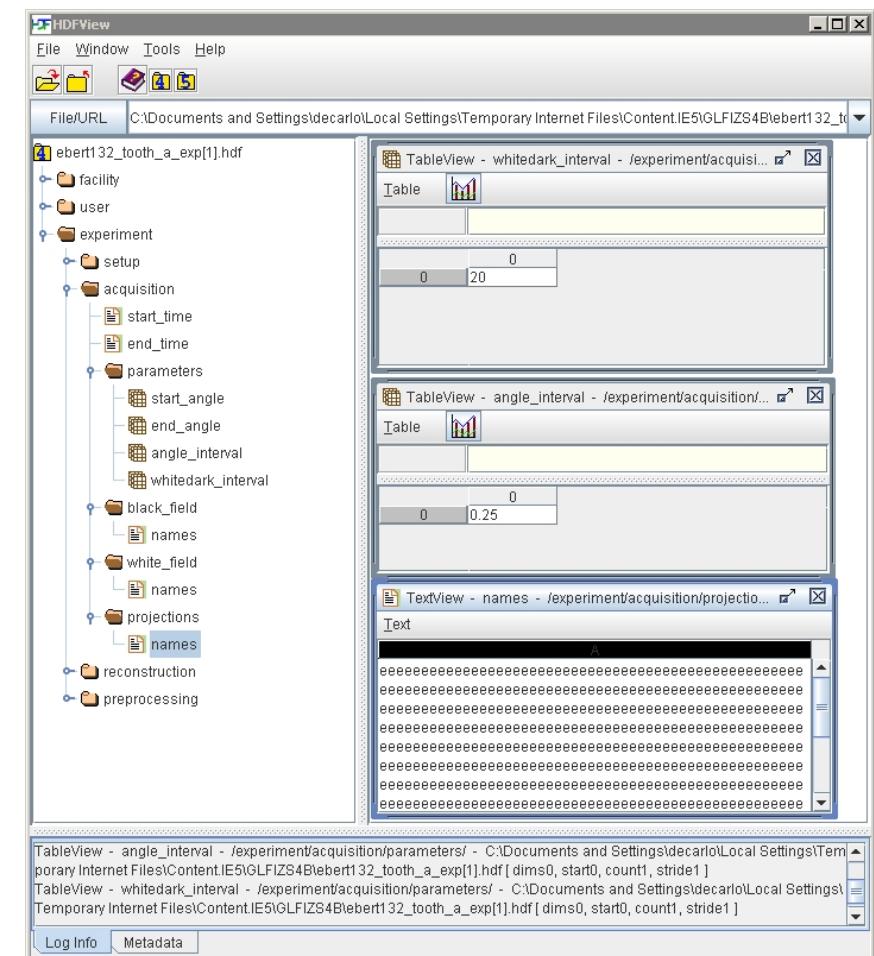
Sample Folder

 SampleName_exp.hdf (meta data)
 raw
 SampleName_0001.hdf
 SampleName_0002.hdf

 SampleName_0796.hdf



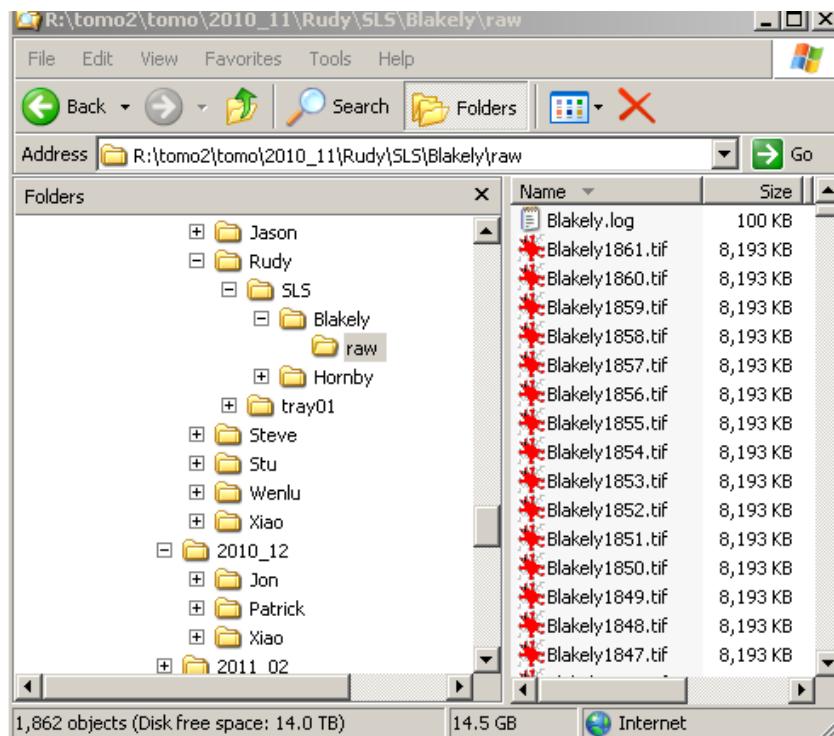
2-BM raw data format



Sample Folder
raw\

 SampleName.log (ascii meta data)
 SampleName_0001.tif
 SampleName_0002.tif

 SampleName_0796.tif



SLS raw data format

Hornby_b.log - WordPad

User ID : e11218
FAST-TOMO scan of sample Hornby_b started on Mon Nov 08 13:54:57 2010

----- Beamline Settings -----

Ring current [mA] : 401.199
Beam energy [keV] : 19.260
Monostripe : Ru/C

----- Detector Settings -----

Objective : 10.00
Scintillator : LAG 20mu
Exposure time [ms] : 170

----- Scan Settings -----

Sample folder : /sis/X02DA/data/e11218/Data20/disk3/Hornby_b
File Prefix : Hornby_b
Number of projections : 1441
Number of darks : 20
Number of flats : 200
Number of inter-flats : 1
Inner scan flag : 1
Flat frequency : 0
Rot Y min position [deg] : 0.000
Rot Y max position [deg] : 180.000
Angular step [deg] : 0.125
Sample In [um] : 0
Sample Out [um] : 3000

----- Sample coordinates -----

X-coordinate : 3093.60
Y-coordinate : -2720.00
Z-coordinate : 4513.00
XX-coordinate : -1293.12
ZZ-coordinate : 1347.80

----- Start logging activity... -----

TOMOGRAPHIC SCAN STARTED
Acquiring initial dark images
rotY = 0.000, file: Hornby_b0001.tif

Other facility

Beamline	raw	reconstructed	meta data
2-BM	hdf4 1 file/projection	hdf4 1 file/slice	hdf4
13-BM	Princeton Instruments .SPE files converted into .volume (binary with header, 3-D 16-bit integer array)	.volume binary with header 3-D 16-bit integer array	binary header
26-ID	.txrm	.txrm	in the file
32-ID	.txrm	.txrm	in the file
SLS Tomcat	tiff 1 file/projection	tiff 1 file/slice	ascii

Can we find a way to share Data?

Data Exchange format

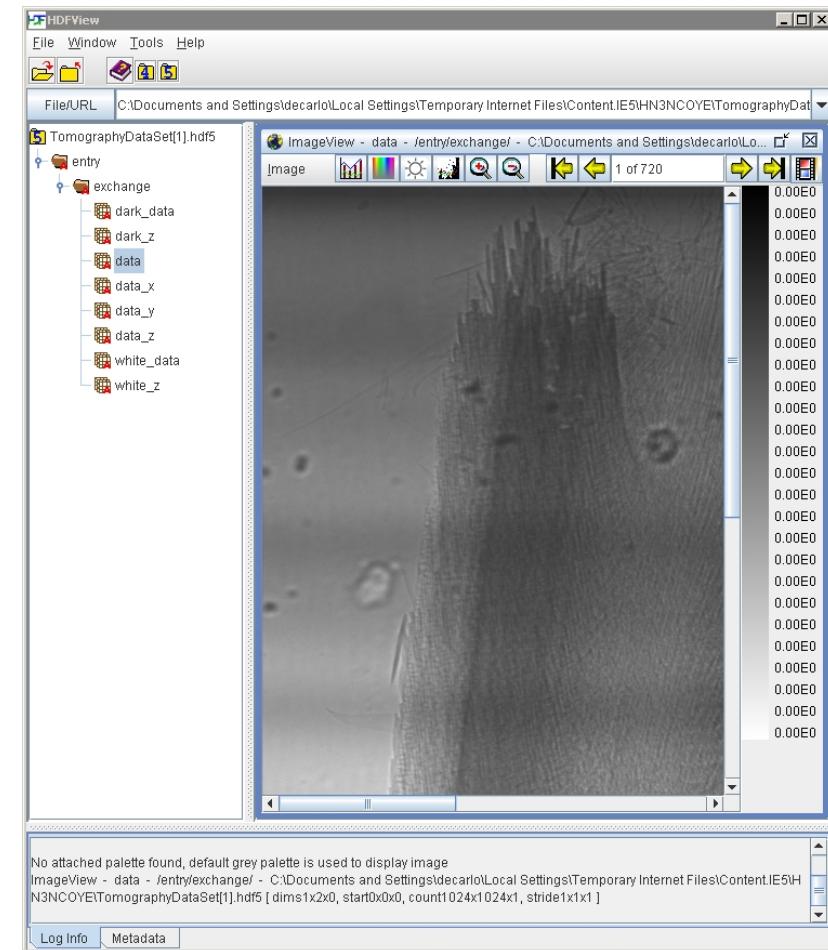


Data Exchange format

Single file for data and meta data
TomographyDataSet.hdf5

Simple Rules:

- Data exchange definition
- Data are 3D arrays (2D image + angle) for projections, white and dark fields
- 2D image sizes are fixed (CCD height-width)
- 1 D (angle) are unlimited and extensible
- Natural HDF5 dims order
 - Height dim[1]
 - Width dim[2]
 - Depth dim[0]
- Data written in chunk of 2D image size



Exchange data among facilities:

APS ⇔ SLS ⇔ ESRF ⇔ Soleil ⇔ Diamond
Petra III ⇔ Anka ⇔ NSLS II

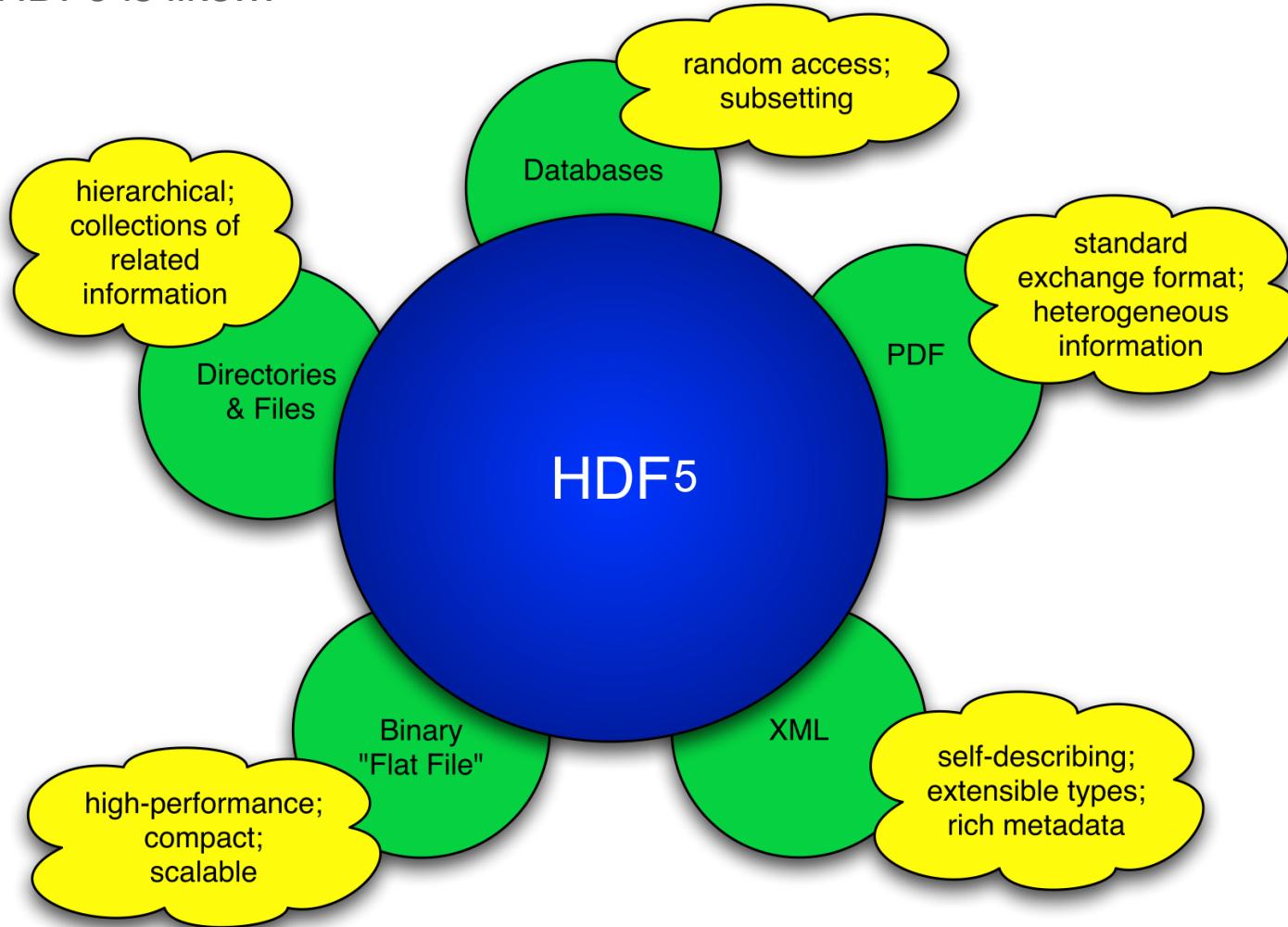
APS lead:

Data analysis tools using data exchange files
Data exchange as native PCO camera format



File Format: HDF5 ?

HDF5 is like...



From Barbara Jones at the HDF/HDF-EOS Workshop XIII November 3-5, 2009



HDF5 is designed ...

- for high volume and/or complex data
- for every size and type of system (portable)
- for flexible, efficient storage and I/O
- to enable applications to evolve in their use of HDF5 and to accommodate new models
- to support long-term data preservation

HDF5 is a data model, library and file format for managing data.

<https://hdri-sdf.desy.de/>



Data Exchange Shared Meta Data Definitions

----- User -----
----- Beamline -----
----- Sample -----
----- Acquisition -----
----- Detector -----
----- Reconstruction -----



Data Exchange Shared Meta Data Definitions

-----User-----

ID : e11218 {GUP25511}
Name : Rudy Wenk
Affiliation: University of California, Berkeley
Address : EPS / UC Berkeley CA 94720-4767 USA
Phone : +1 510 642 7431
E-mail : wenk@berkeley.edu

-----Beamline-----

Facility : Tomcat {APS 2-BM}
Ring current [mA] : 401.096
Beam energy [keV] : 19.260
Monostripe : Ru/C



Data Exchange Meta Data Definitions

-----Sample-----

Name	: Blakely
Description	: GUP25511.pdf
Environment	: air
Temperature [C]	: 25
Pressure [Pa]	: N/A
Reference Outboard	: X+
Reference Up	: Y+
Reference Beam	: Z+
Reference Rotary	: Y+
X-coordinate [um]	: 66.60
Y-coordinate [um]	: 4380.00
Z-coordinate [um]	: 5506.00
XX-coordinate [um]	: -810.12
ZZ-coordinate [um]	: 1612.80
Detector Distance [mm]	: 12
Raw Data Directory	: /data/e11218/Data20/disk3/Blakely/



Data Exchange Meta Data Definitions

-----Acquisition-----

Type	: FAST-TOMO {FLY-SCAN}
Start Time	: Mon Nov 08 14:51:56 2010
End Time	: Mon Nov 08 15:06:50 2010
Number of projections	: 1441
Number of darks	: 20
Number of flats	: 200
Inner scan flag	: True
Flat frequency	: 0
Number of inter-flats	: 1
Rot Y min position [deg]	: 0.000
Rot Y max position [deg]	: 180.000
Angular step [deg]	: 0.125
Angular speed [deg/s]	: {0.2}
Sample In [um]	: 0
Sample Out [um]	: 3000
Interferometer Grid Start [um]	: [0]
Interferometer Grid End [um]	: [2.4]
Interferometer Grid position [um]	: <1.3>
Interferometer N of grid steps	: [8]



Data Exchange Meta Data Definitions

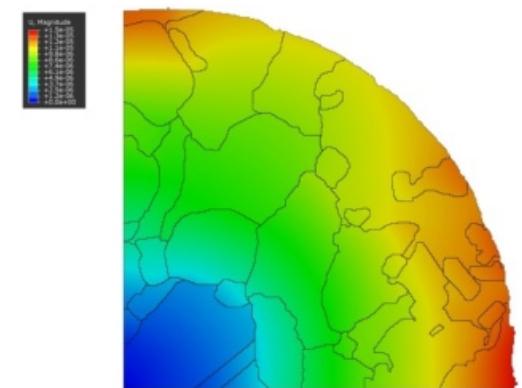
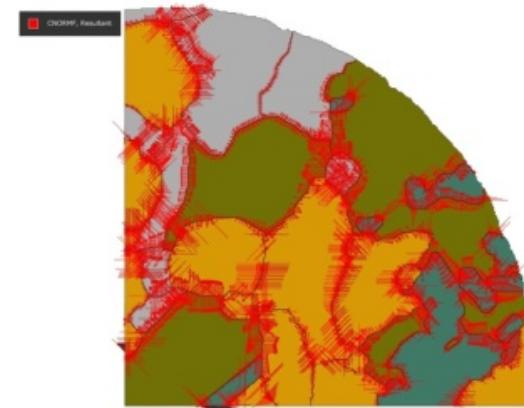
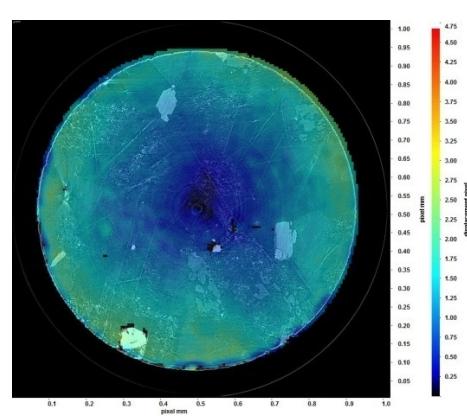
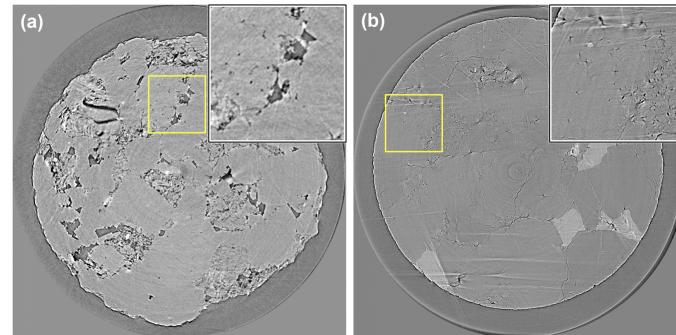
-----Detector-----

Manufacturer	: CooKe Corporation
Model	: pco.dimax
Serial Number	: 1234XW2
Bit Depth	: 12
Objective Magnification	: 10.00
Effective Pixel Size [um]	: 0.7
Scintillator	: LAG 20mu
Exposure time [ms]	: 170
Over Sampling	: 1
Frame Rate [fps]	: {2}
Image size (H) [pixel]	: 2048
Image size (V) [pixel]	: 2048
Image Horizontal Axis	: X+
Image Vertical Axis	: Y+



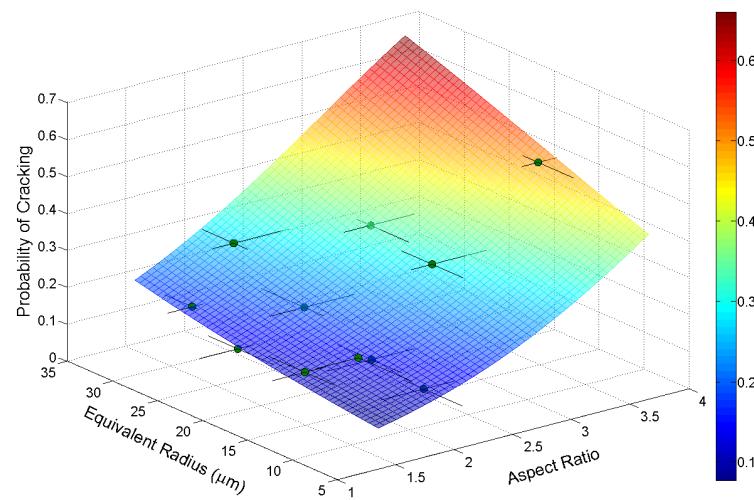
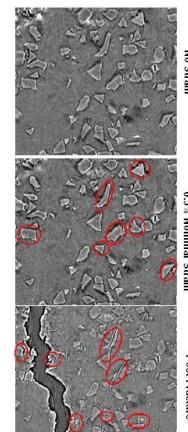
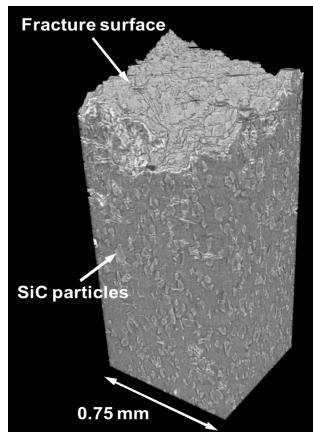
Data reduction and modeling

Thermal Expansion Displacement in rocks



Data reduction and modeling

3D Analysis of Probability of Cracking as a function of Particle Size and Aspect Ratio



Thank you



- on-demand data analysis
 - 2-BM Tomography CPU/GPU cluster
 - APS shared cluster
 - APS development cluster



PJ0200: GPU tomography

PJ0200: GPU spectroscopy

Terminal

KVM

oss0202: lustre data storage

oss0203: lustre data storage

Mds0200/ 2001: lustre meta data RAID

oss0200: lustre data storage

oss0201: lustre data storage

mds0200 : lustre meta data server

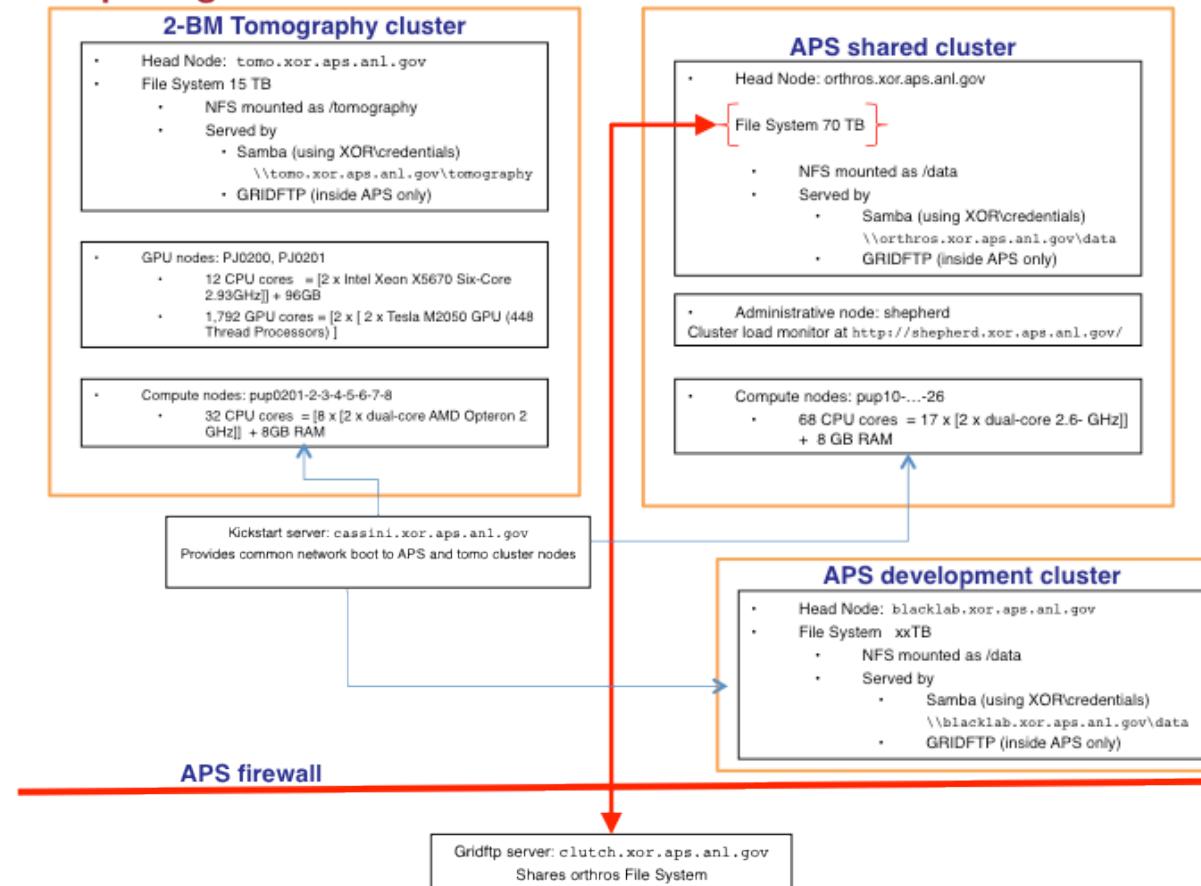
mds0201 : lustre meta data server backup

Compute nodes: pup0201-2-3-4-5-6-7-8

Micro tomography of static samples

High Performance Computing Infrastructure

Computing Infrastructure



Micro tomography Experiment Tasks

Shutter Status: PA:02BM:126:02.VAL [Green Bar]

Shutter Control: 2bma:monoshutter:select.VAL [Red Bar]

Beam Current: S:SRcurrentAI 101.45111130773913

ACIS Permission: ACIS:ShutterPermit [Green Bar]

OK Cancel

Manufacturer	Model	Comment
Zeiss	1.25x	5.08 um/pixel
Zeiss	4x	1.66 um/pixel
Zeiss	5x	1.33 um/pixel
Zeiss	10x	0.66 um/pixel
Zeiss	20x	0.33 um/pixel
Zeiss	Tube Lens	Standard 1x AXIOPLAN mic...

Add

Order	Manufacturer	Model	Comment
1	Zeiss	Tube Lens	Standard 1x AXIOPL...
2	Zeiss	5x	1.33 um/pixel

Remove

OK Cancel

Scintillators: CdW [Selected]

Scintillator: Unknown
CdW
Name: YAG1
Type: YAG5

Substrate Thickness: 300um

Scintillating Thickness: 300um

Comments: Polished

OK Cancel